AN ALTERNATIVE CODING SYSTEM DEFINING THE TOTAL AND SEVERITY OF WEAR

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Abstract: A ferrous debris monitor is described which is capable of measuring the concentration of ferrous wear debris suspended in a lubricant and the severity of wear associated with particle size of this suspended debris. A coding system is proposed : PQ index(total wear):initial TDPQ slope(large particles):final TDPQ slope(small particles). Correlation with existing measurements is detailed.

Keywords: Ferrography; Ferrous Debris Monitor; Spectroscopy; Time Dependent Particle Quantifier;

Introduction: Users of spectrographic oil analysis have, for some considerable time, been aware of the limitation of this technique in relation to the accuracy of this method when analysing samples which contain particles larger than 5um. Emission, absorption and inductively coupled plasma spectrometers are each limited in their ability to analyse these large particles.

Direct-read ferrography, Wear Particle Analyser (Tribometrics), the ferrous wear debris monitor (PQ90) and the use of magnetic plugs have addressed this problem. These techniques are however, restricted to measuring ferrous wear debris. Most equipment, however, which generate large particles, gearboxes for example, produce ferrous wear debris and it is this material which is monitored.

The ferrous debris monitor (PQ90), which is a sensitive magnetometer, measures the quantity of ferrous wear debris in a sample without the disadvantages of time and dilution requirements associated with the other techniques. The unbalanced condition is measured and displayed as the 'PQ Index'. This index is measured in arbitrary units which may be correlated with the Dl and Ds ferrographic measurements. These measurement units, like all concentration measurements obtained by spectroscopy, should not be considered absolute measurements due to particle size sensitivity of each technique.

Correlation of the PQ Index with other measurements: The introduction of a new technique requires an assessment of the correlation of the measurement with measurements obtained by techniques already in use. The following results were prepared by Wearcheck, South Africa.

There was good correlation between the PQ Index and Iron measured by ICP for samples taken from diesel engines and transmissions. Both these types of component generate a higher percentage of small particles, typically less than 10um: correlation would therefore be expected. The case of drive trains (final drive axle units) indicates less correlation between the PQ Index and ICP measurement of iron than for either engine or transmission units. In practice, the drive train units generate a greater population of larger particles than for the other components.

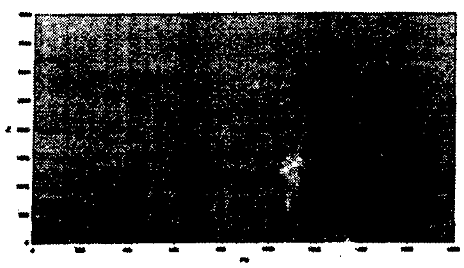


Figure 1 Correlation : 961 Engine Samples

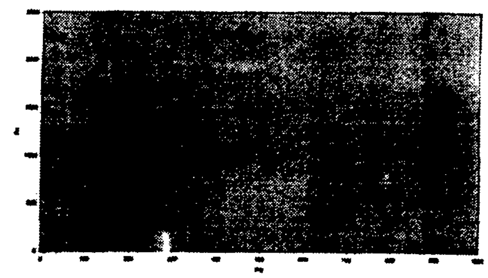


Figure 2 Correlation : 762 Transmission Samples

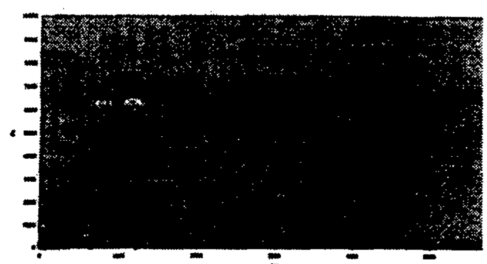
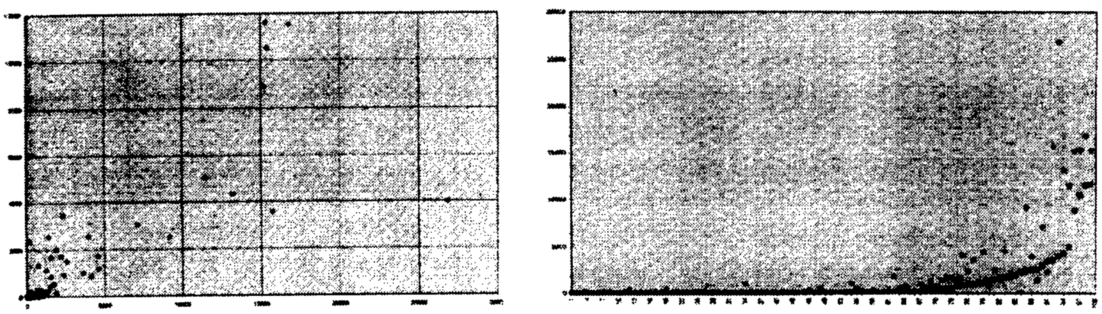


Figure 3 Correlation : 3310 Final Drive Damples

Direct - ead ferrography measures the large and small particles by magnetic separation. The summation of Dl + Ds may be considered a measurement of the total wear debris separated from a fixed volume of sample. The PQ Index may also be considered a similar measurement. The volume of the sample is not however critical when using the PQ90 instrument.

The following figures show the correlation between Dl + Ds and the PQ Index for over 200 samples. These samples were taken from diesel engines, transmissions, drive units and hydraulic components.The correlation in Figure 5 has been drawn as a function of increasing values of the PQ Index. Both figures show good correlation between the two techniques.



Figures 4 and 5 Correlation between PQ Index and Dl+Ds Ferrography

The Case for a New Coding System: The development of the bottle method measures the sedimentation rate of particles in a sample of fluid which may be related to the severity of wear that has occurred in the sampled machine. A 20 to 30ml plastic bottle provides an adequate volume of sample for the ferrous debris monitor. As particles settle, the effective particle concentration will increase in the region subjected to the measuring field. The TDPQ method measures the magnetic out of balance at 10 second time intervals for a total of 100 seconds.

Previous reported results (1) of samples of oil with controlled concentrations and proportions of various size ferrous particles show, in a number of cases, a higher initial rate increase of the PQ index. The rate of increase of the PQ index decreases with time. Relating these rate increases to the particle size distribution suggests a possible method for measuring the severity of wear occurring within a machine.

Figures 6 and 7 show the higher initial rate of change of the PQ index. In these examples particles larger than 100um appear to have a higher rate of sedimentation, as perhaps would be expected, than the smaller particles. Particles less than 50um in size and in concentrations of 1000 and 500 ppm continue to settle over a 100 second interval.

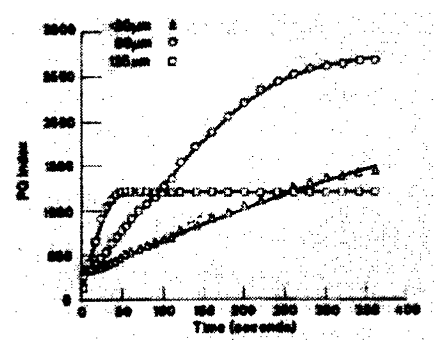


Figure 6 PQ Index as a function of time

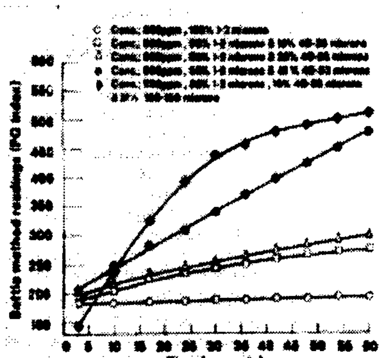


Figure 7 PQ Index as function ot time

This last observation has provided a possible source of a measurement of severity of wear. The combination of PQ Index, initial TDPQ slope and final TDPQ slope may offer a coding system suitable for measuring the total and severity of wear occurring in lubricated equipment. The next section illustrates the practical implication of these observations.

Application of the TDPQ to Field Samples: A series of 21 samples were analysed from earth moving equipment. Components included diesel engines, transmissions, hydraulics and final drive axle units. These units were selected at random from part of a typical daily sample batch received at the laboratory.

Diesel Engine Units: Figure 8 shows results which are typical of diesel engine units. The PQ index for an engine is usually less than 30 and the index remains constant with time. From the previous discussion these results would be expected to be typical of a sample with only small particles present. Figure 9 shows the Rotary Particle Deposit (RPD) associated with one of these samples. The particles deposited are all less than 10um and, as expected, when compared with spectrographic analysis show good correlation. For example the samples which provide PQ indices of 30 and less have iron concentrations less than 60 ppm. The sample with a PQ index of 56-70 measured 174 ppm iron by spectroscopy.

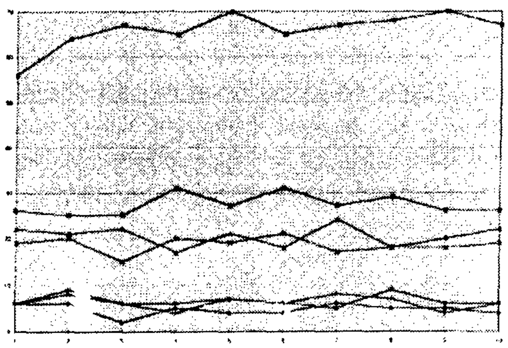


Figure 8 TDPQ readings for Diesel Engine samples

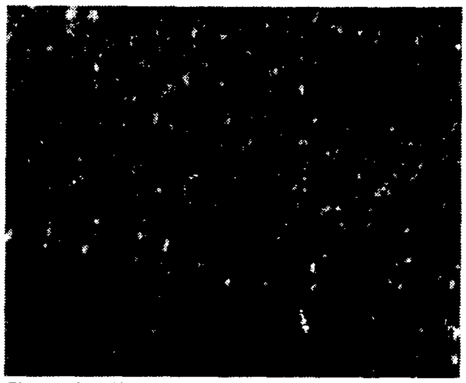


Figure 9 RPD typical particles of a diesel engine

Transmission Units: Figure 10 shows a summary of the TDPQ results for two of the transmission units tested. These graphs show a similar trend to that obtained for diesel engines i.e. a constant PQ index for the test duration. Figure 11 shows the particles that were deposited by the RPD. It will noted that the particles are all less than 10um and would therefore all be analysed by spectrographic methods.

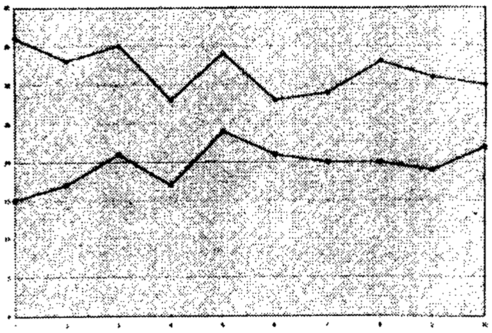


Figure 10 TDPQ for transmission samples

Figure 11 RPD for transmission sample

Final Drive Axle Units: Figure 12 summarises the TDPQ results obtained for nine final drive axle units. Each of the units has a higher initial TDPQ slope than that obtained for the latter stages. One example suggests an anomaly, i.e.a much higher TDPQ slope although all the samples had spectrographic results for iron of between 350 and 600 ppm. Figure 13 through 16 show the reason for this anomaly. The sample which had the high TDPQ slope also had a high density of larger ferrous wear particles. These particles varied in size from 30 to 300 um. These larger particles would not be expected to be analysed by spectroscopy which has the size limitation for analysis.

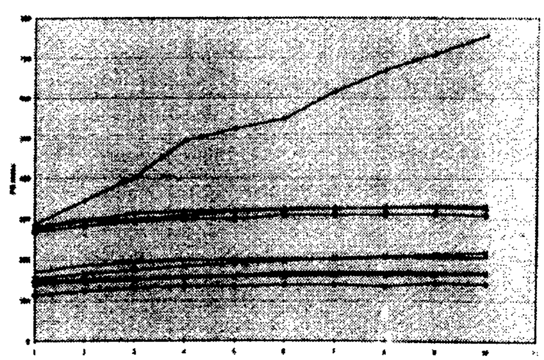


Figure 12 TDPQ for Final Drive Axle samples

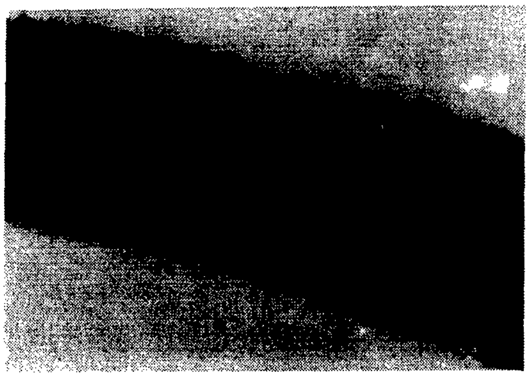


Figure 13 RPD inner ring Final Drive Axle TDPQ slope average for Drive Train

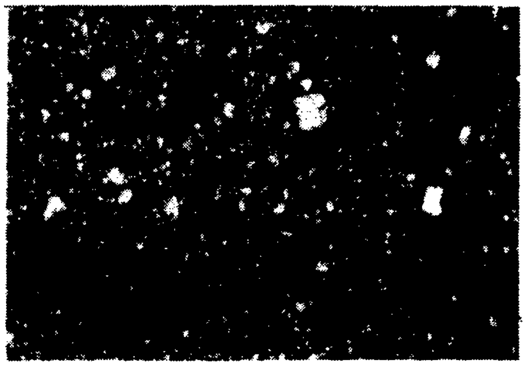


Figure 14 Low level of particles larger than 50 μm

Figure 15 RPD inner ring for Final Drive Axle sample. TDPQ slope higher than other samples

Figure 16 Numerous particles larger than 100μm

The following example further illustrates the effect of large particles on the spectroscopy and TDPQ measurements. A low, acceptable spectroscopy reading of 22ppm of iron was measured whilst the PQ index was 582 and 430 Dl and 113 Ds abnormal readings for this transmission unit. The TDPQ initial slope was higher than average whereas the final TDPQ slope had fallen to a low level. This result, from the above observations, would point to a proportion of large particles (greater than 100um) in a suspension of particles less than 10um. The following SEM micrographs show the supporting evidence.

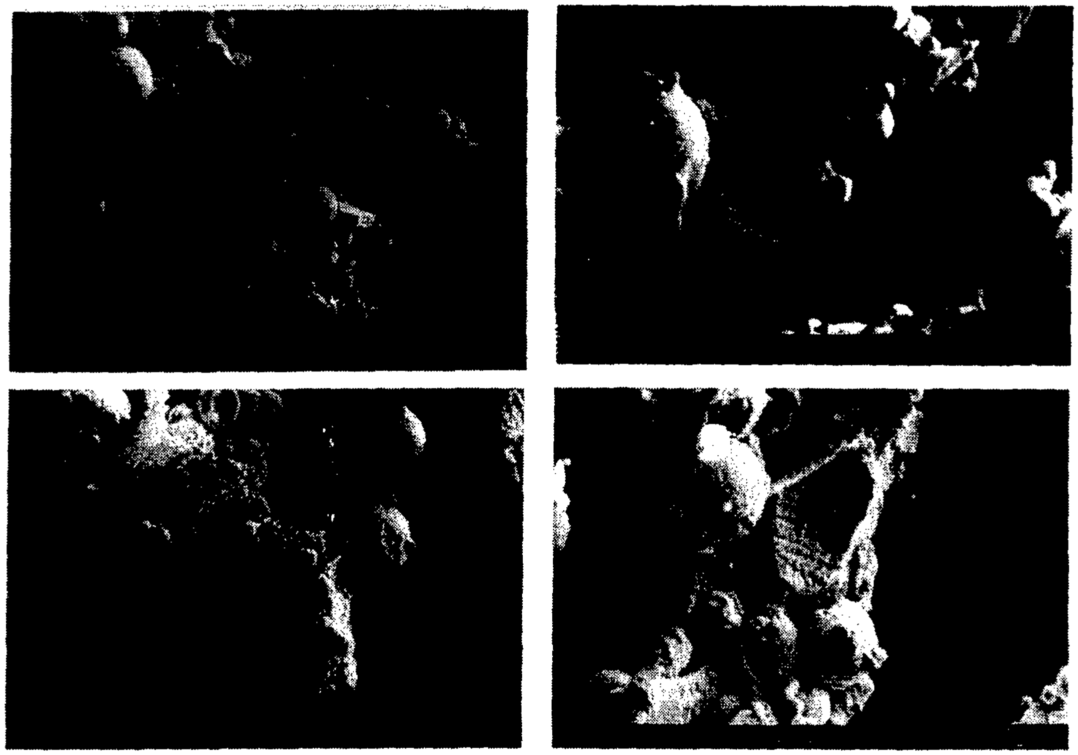


Figure 17 Stereo Electron Micrographs of an RPD of Final Drive sample with a high TDPQ initial slope

A proposal is therefore make to consider a coding system which includes PQ Index : initial TDPQ slope : final TDPQ slope.

The PQ Index is a measurement of total level of wear : initial TDPQ slope is a measurement of large particles : final TDPQ slope a measurement of the proportion of small particles.

Conclusions: The Time Dependent Particle Quantifier (TDPQ) offers both a portable and laboratory based instrument capable of measuring the total amount and severity of wear occurring in mechanical equipment. This instrument, in its portable mode, would provide a simple site screening technique capable of selecting fluid samples which should be sent to a central laboratory for further tests.

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References

1. Jones M.H. and Massoudi A.R.; The TDPQ ; a solution to the analysis of large wear particles. Insight, vol 37 No.8 August 1995.